Long-Term Trends and Variability of Suisun Marsh Salinity

IEP Workshop
February 26, 2004

Chris Enright
Suisun Marsh Branch
DWR

Suisun Marsh Salinity Trends

1. Premise of Suisun Marsh Mitigation
2. Data: precipitation, outflow, salinity
3. Long-term and among-month trends
   - Pre and post water project
4. Suisun Marsh Salinity Control Gate effect
5. Trends since SMSCG construction (1988)
6. Time-scale variability
7. Bathymetry trends also affect salinity

1. Premise of Water Project Involvement in the Suisun Marsh

1. Premise of Water Project Involvement in the Suisun Marsh

- Suisun Marsh salinity will ~triple with water project build out (Mall 1969):

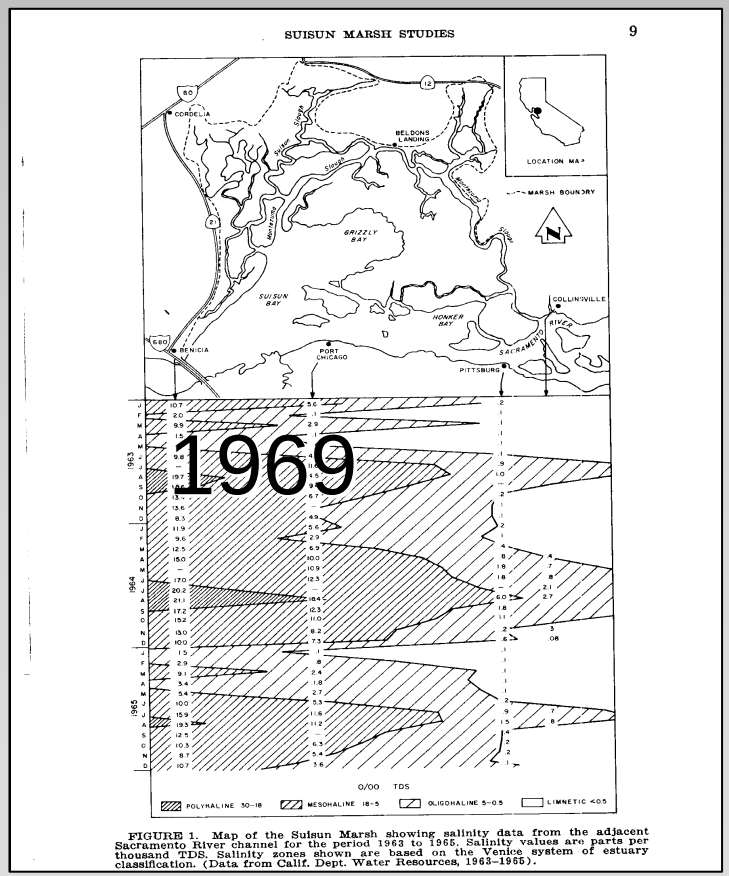


FIGURE 1. Map of the Suisun Marsh showing salinity data from the adjacent Sacramento River channel for the period 1963 to 1965. Salinity values are parts per thousand TDS. Salinity zones shown are based on the Venice system of estuary classification. (Data from Calif. Dept. Water Resources, 1963–1965).

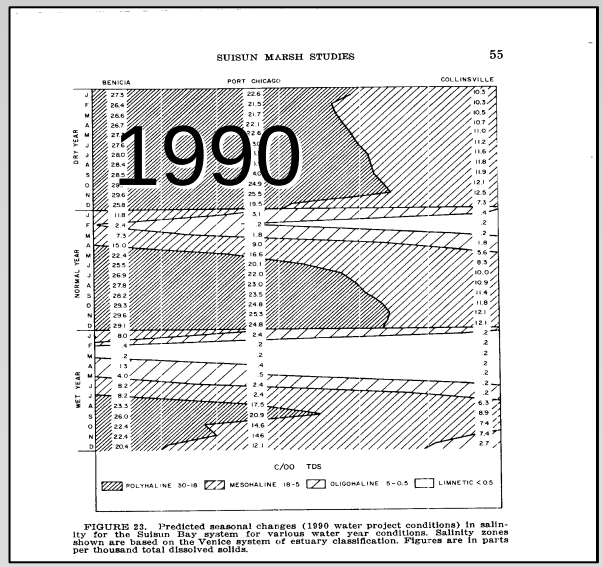


FIGURE 23. Predicted seasonal changes (1990 water project conditions) in salinity for the Suisun Bay system for various water year conditions. Salinity zones shown are based on the Venice system of estuary classification. Figures are in parts per thousand total dissolved solids.

Impacts on what?

- Agreements and regulatory standards are intended to mitigate impacts on **seasonal waterfowl values**.
- Other beneficial uses are not codified as numerical standards yet.

So, the premise for Suisun Marsh mitigation is:

- Reduced outflow

→reduces waterfowl productivity

The premise implies a conceptual cascade of influences:

Reduced outflow: ← ***Water Projects***

- Estuary salinity
  - Applied water salinity
    - Soil water salinity/soil biochemistry
      - Plant productivity and assemblage
        - Waterfowl abundance

The premise implies a conceptual cascade of influences:

Reduced outflow: ← ***Water Projects***

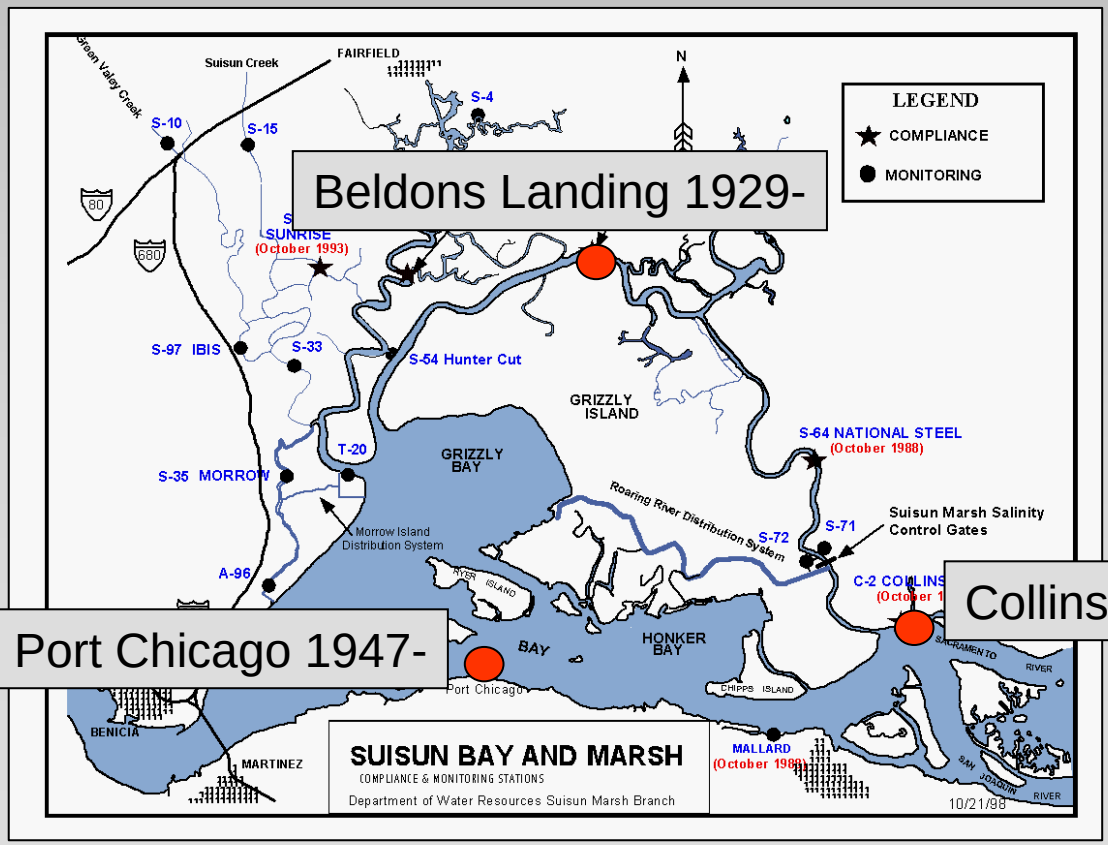
- *Estuary salinity*
  - Applied water salinity
    - Soil water salinity/soil biochemistry
      - Plant productivity and assemblage
        - Waterfowl abundance

There is a project impact:

- Delta outflow ~22% less than it would be.
- The seasonal distribution of outflow is changed:
  - Increased outflow in Aug, Sep, and Oct
  - Decreased outflow in April, May and June

2. Data

- SF Estuary Watershed Precip. (1921-present)
- Delta Outflow (1929 – present)
- 3 Suisun salinity records (1921,29,47 – present)



Historical Suisun Marsh/Bay Salinity 1920 - 2002

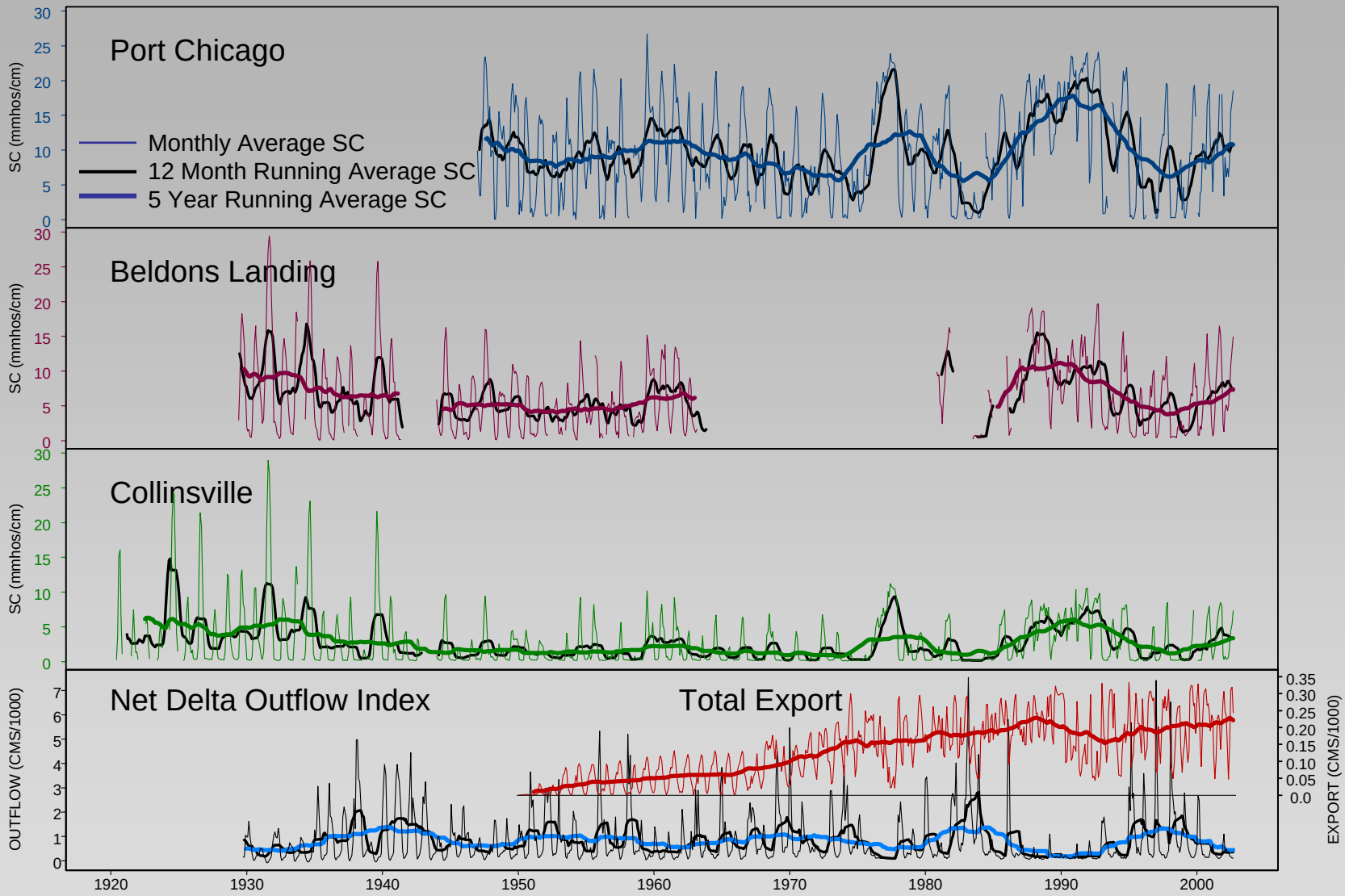
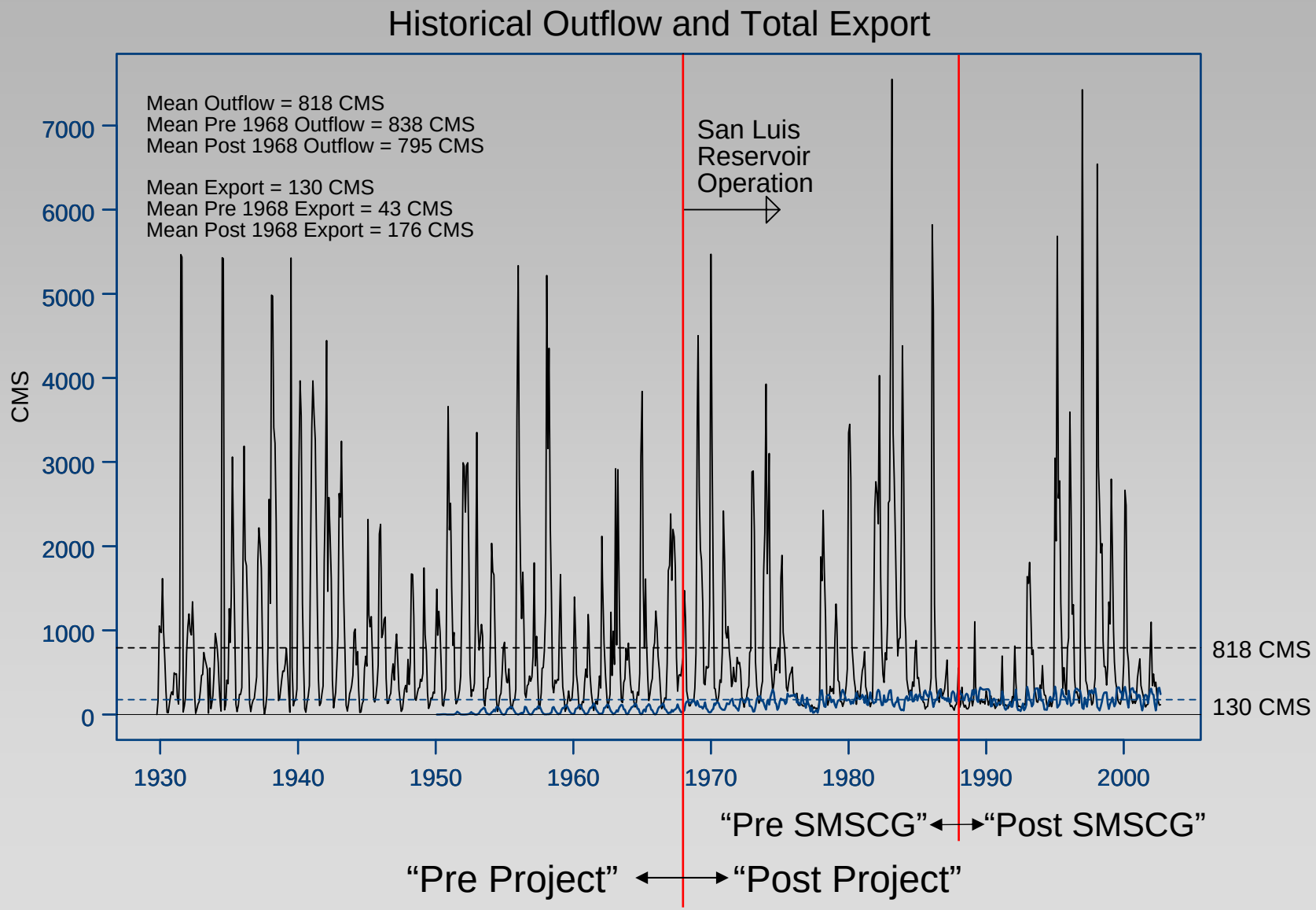
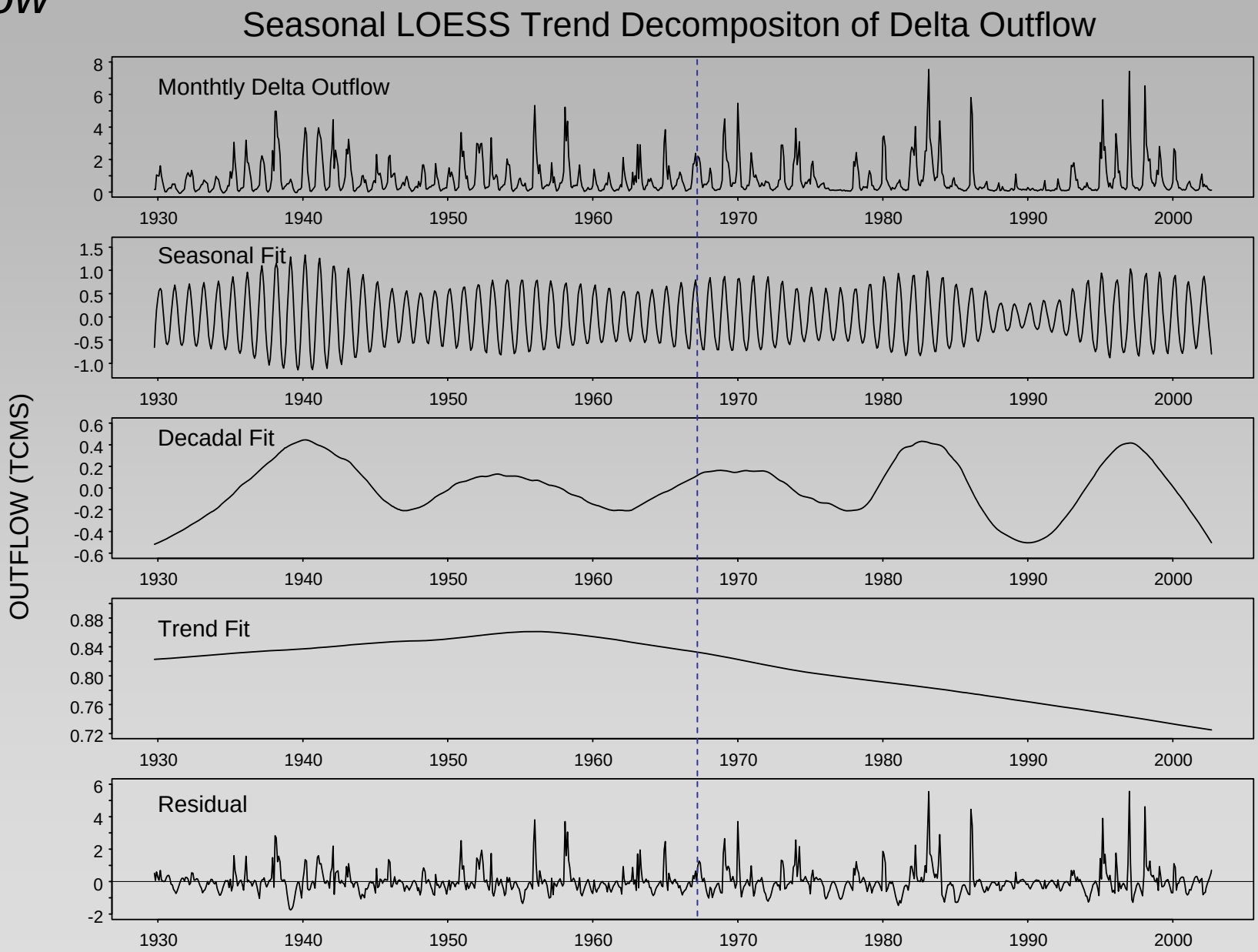


Figure xx. Monthly Average, 12 month running average, and 5 year running average specific conductivity. Prior to 1966, SC estimated from approximately four high tide TDS grab samples per week.

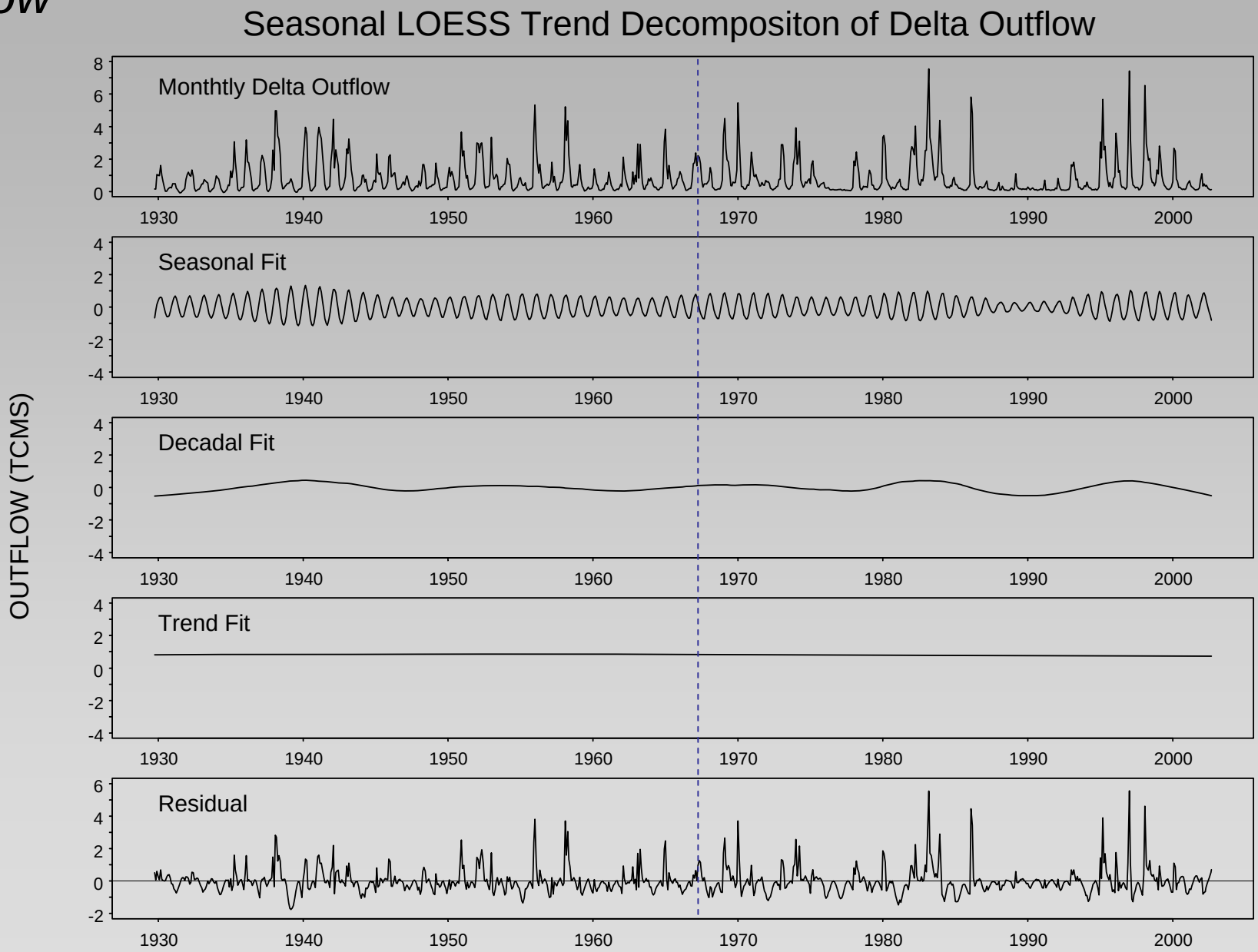
3. Long-Term Trends


Historical Outflow and Total Export
Mean Outflow = 818 CMS
Mean Pre 1968 Outflow = 838 CMS
Mean Post 1968 Outflow = 795 CMS
Mean Export = 130 CMS
Mean Pre 1968 Export = 43 CMS
Mean Post 1968 Export = 176 CMS
San Luis Reservoir Operation
CMS
7000
6000
5000
4000
3000
2000
1000
0
818 CMS
130 CMS
1930
1940
1950
1960
1970
1980
1990
2000
“Pre SMSCG”
“Post SMSCG”
“Pre Project”
“Post Project”

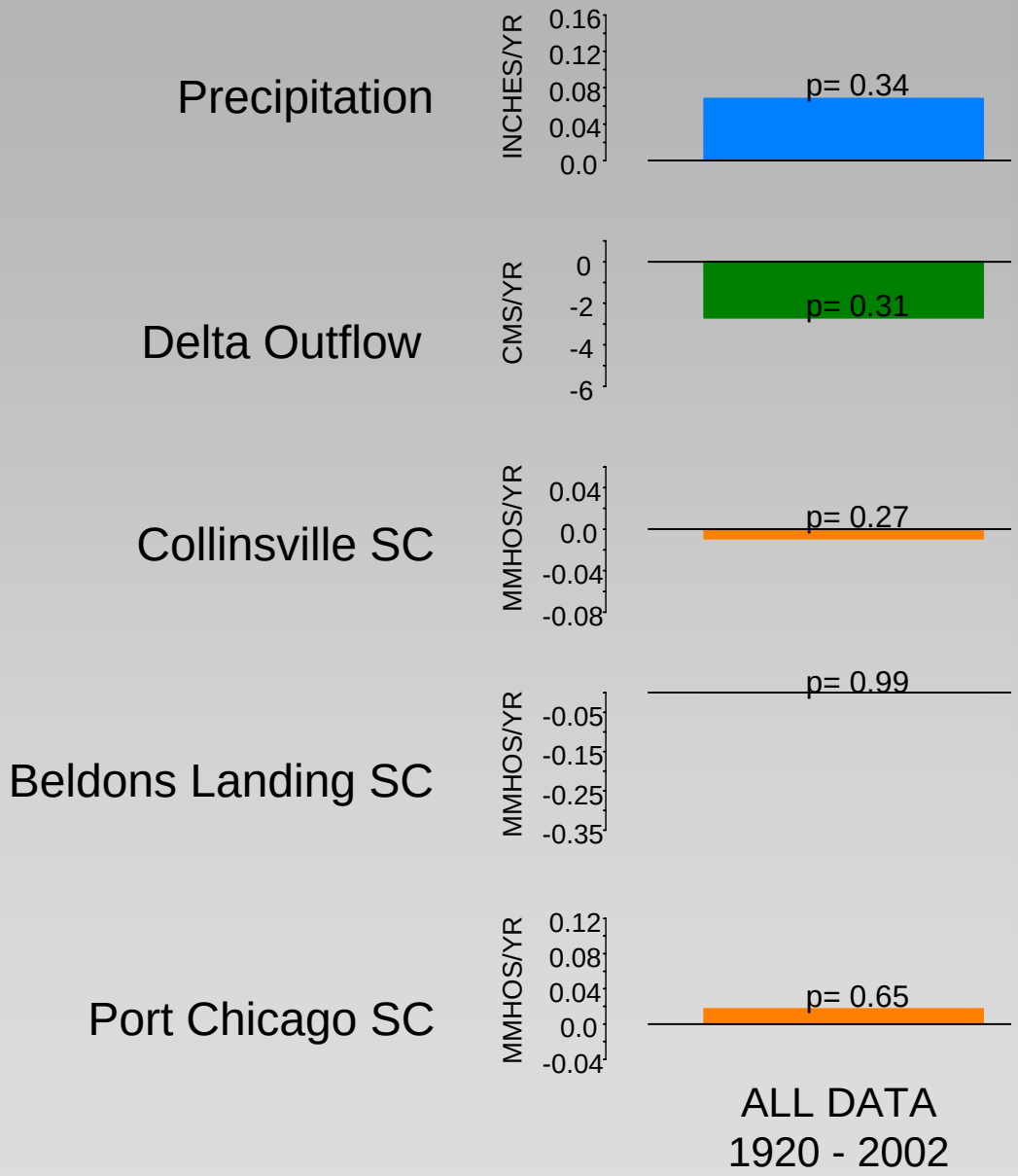
Long-term trend:
Outflow



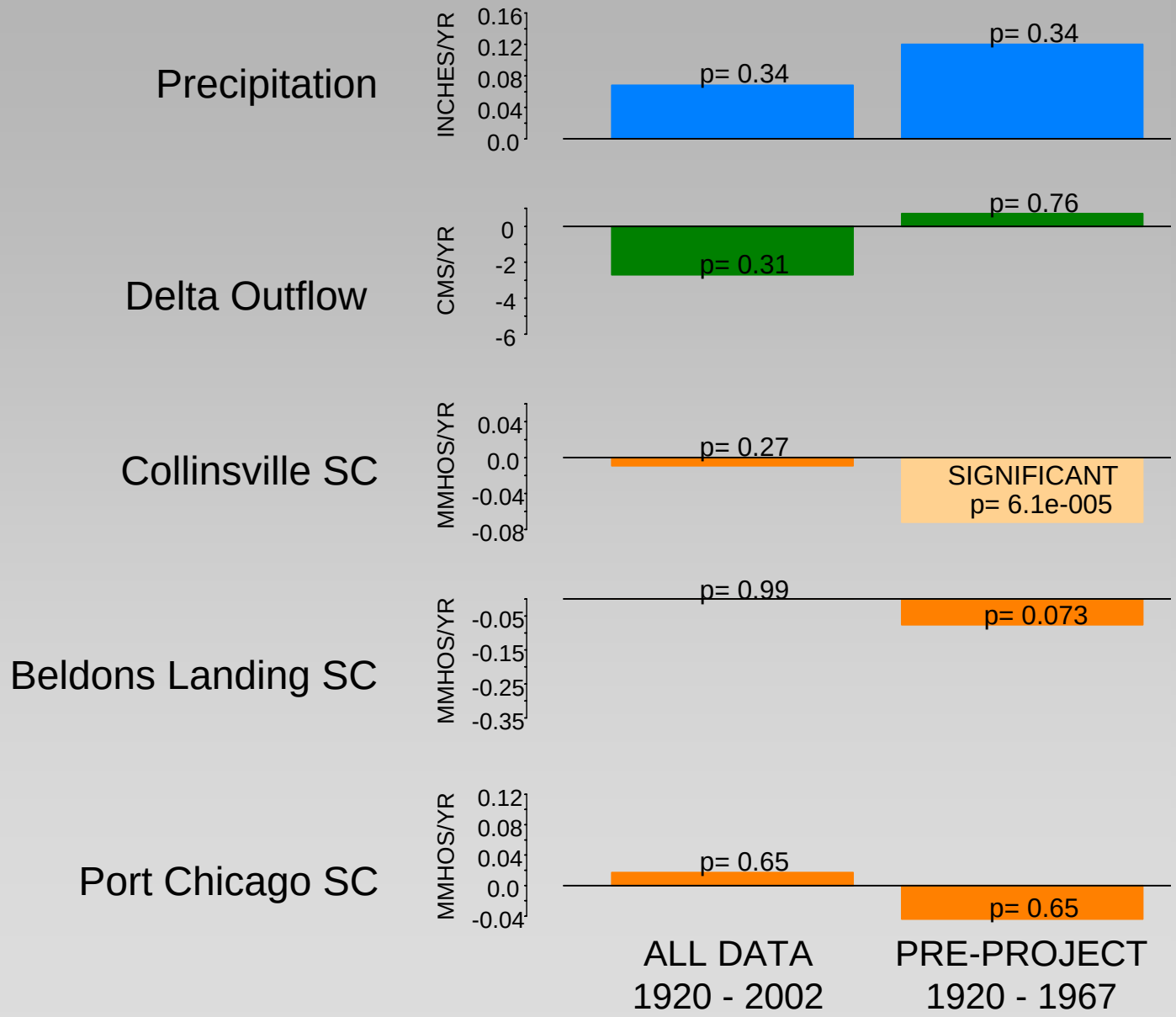
Long-term trend:
Outflow



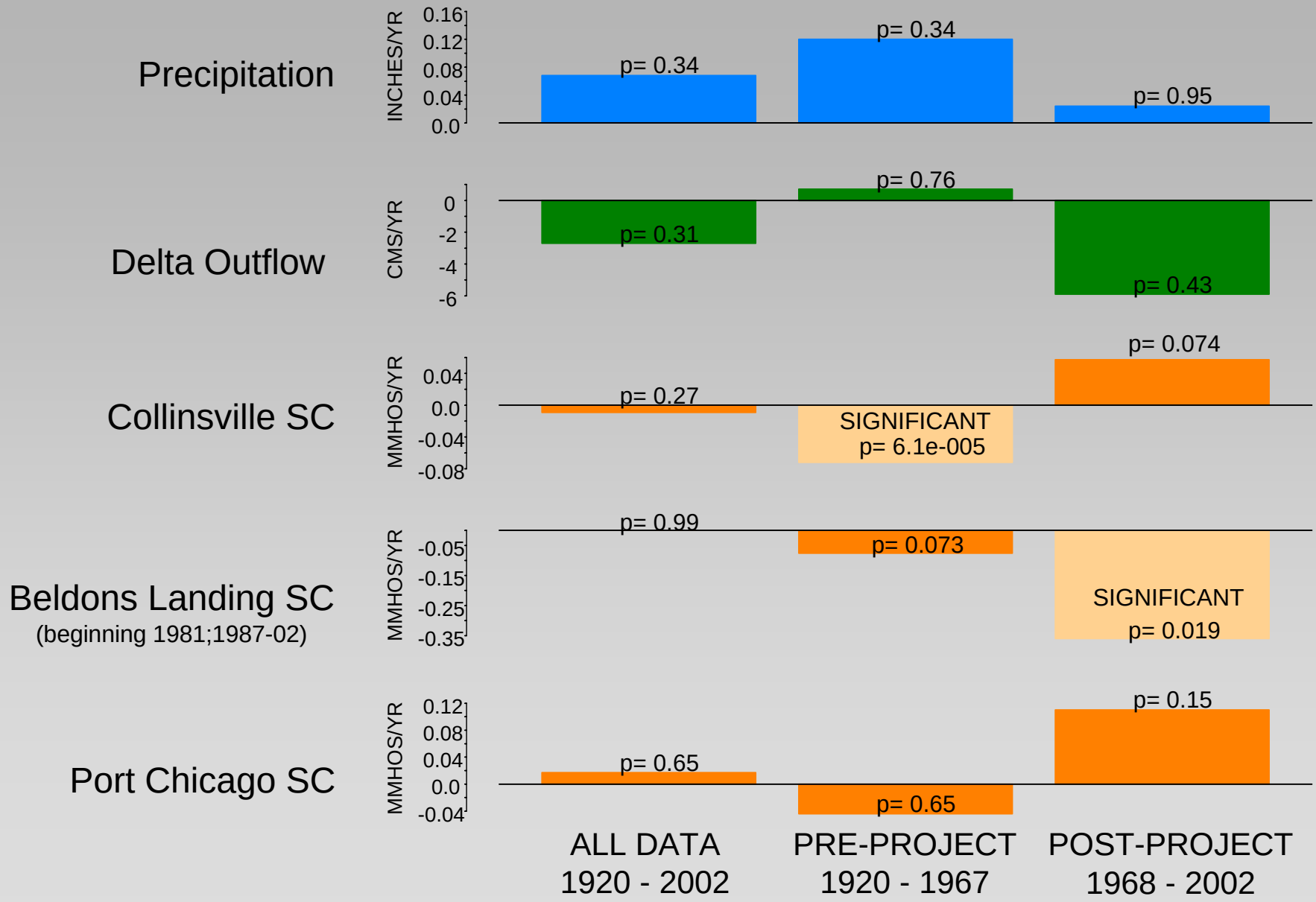
Trends in **Annual** Data (Kendall Tau)



Trends in **Annual** Data (Kendall Tau)



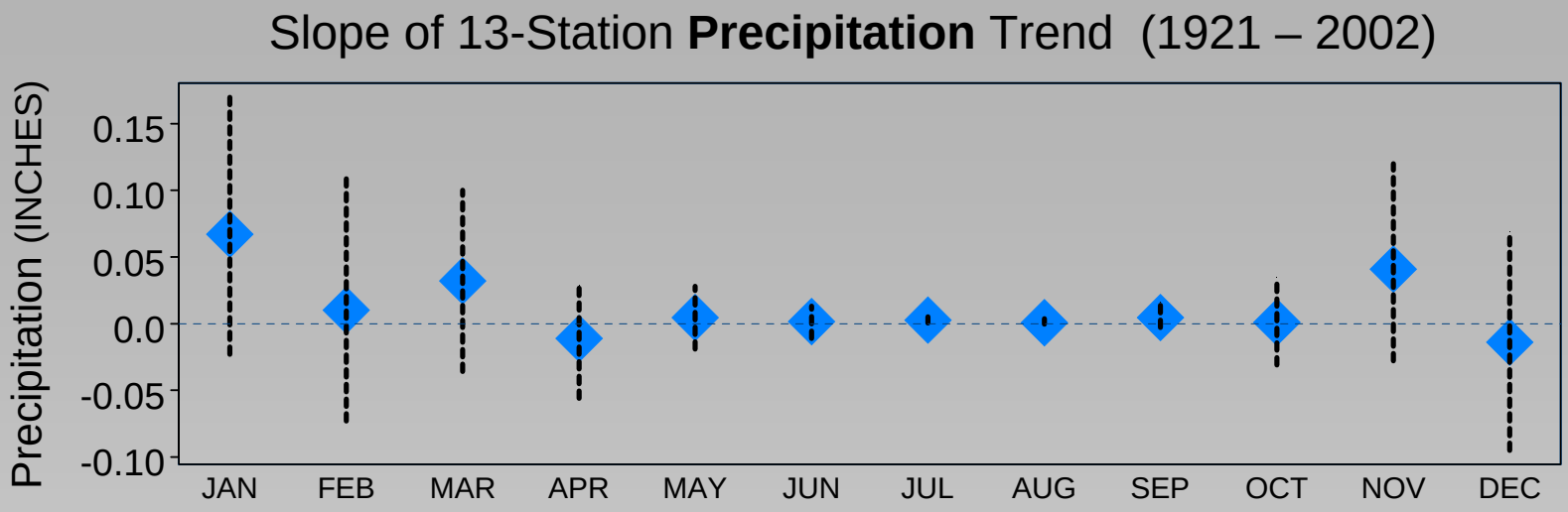
Trends in **Annual** Data (Kendall Tau)



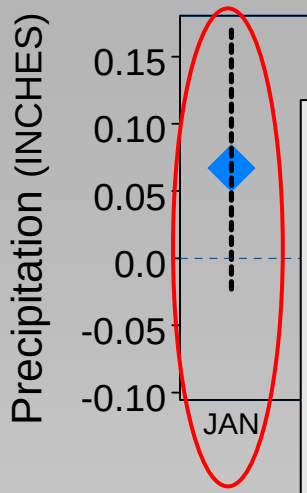
Long-Term Trends:

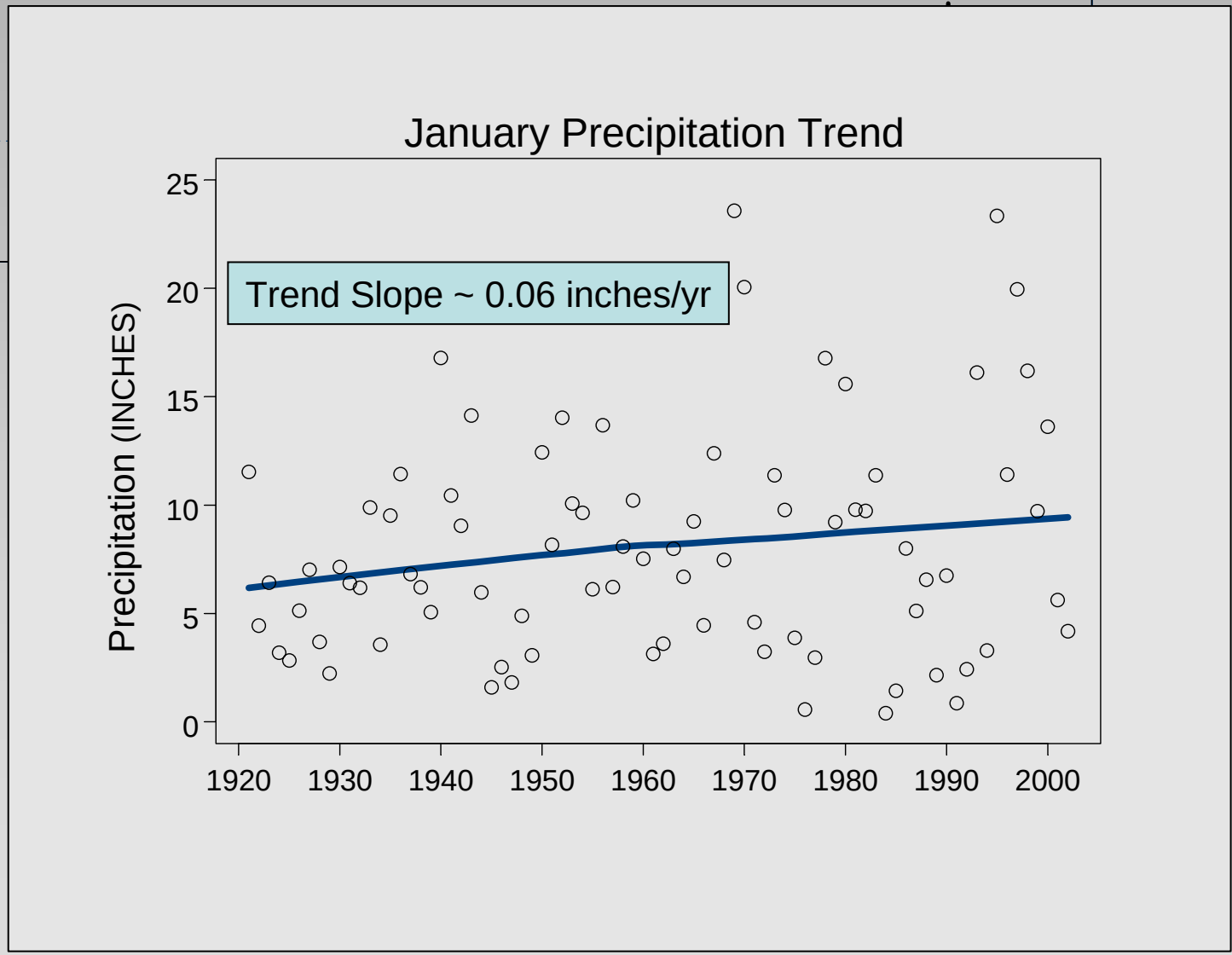
- No tripling of Suisun salinity
- Long-term trends are very small compared to seasonal and tidal variability
- Salinity is anti-correlated with outflow except at Beldons Landing.

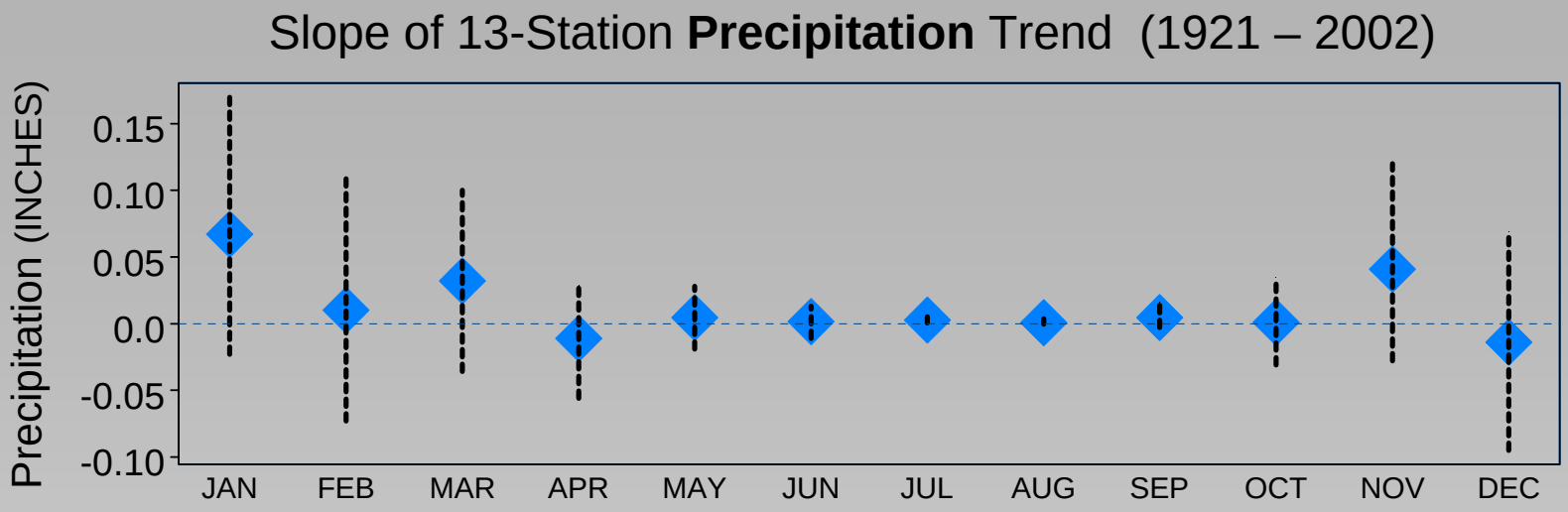
4. Among Month Trends

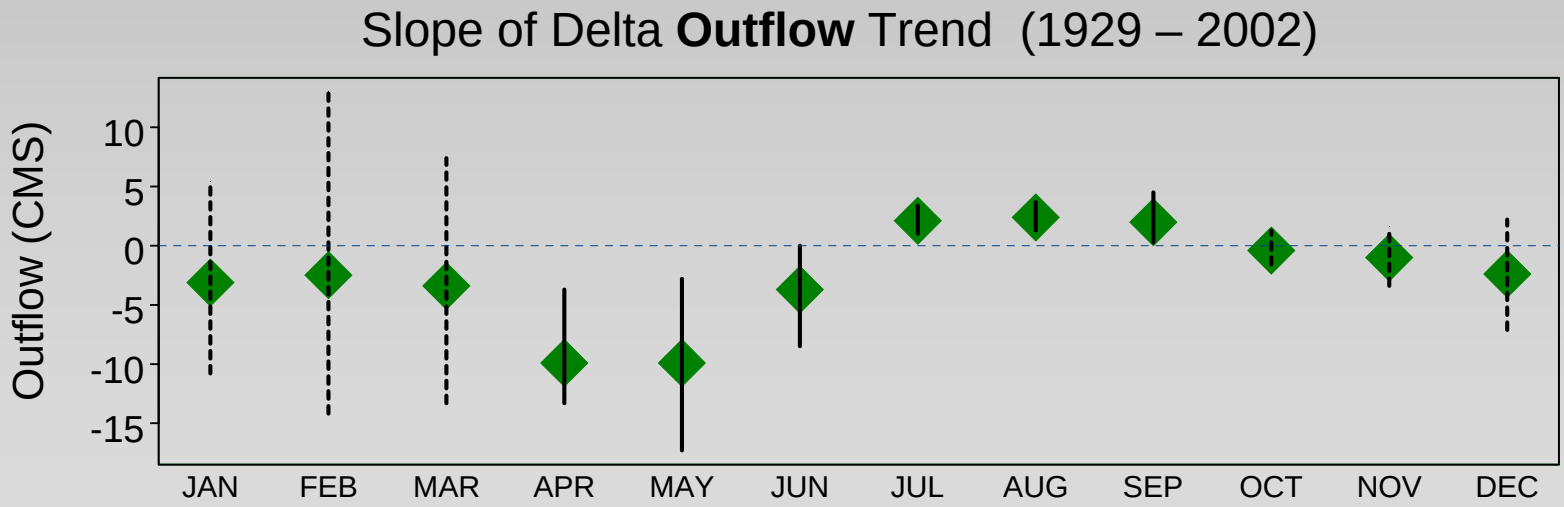

Slope of 13-Station **Precipitation** Trend (1921 – 2002)
Precipitation (INCHES)
0.15
0.10
0.05
0.0
-0.05
-0.10
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

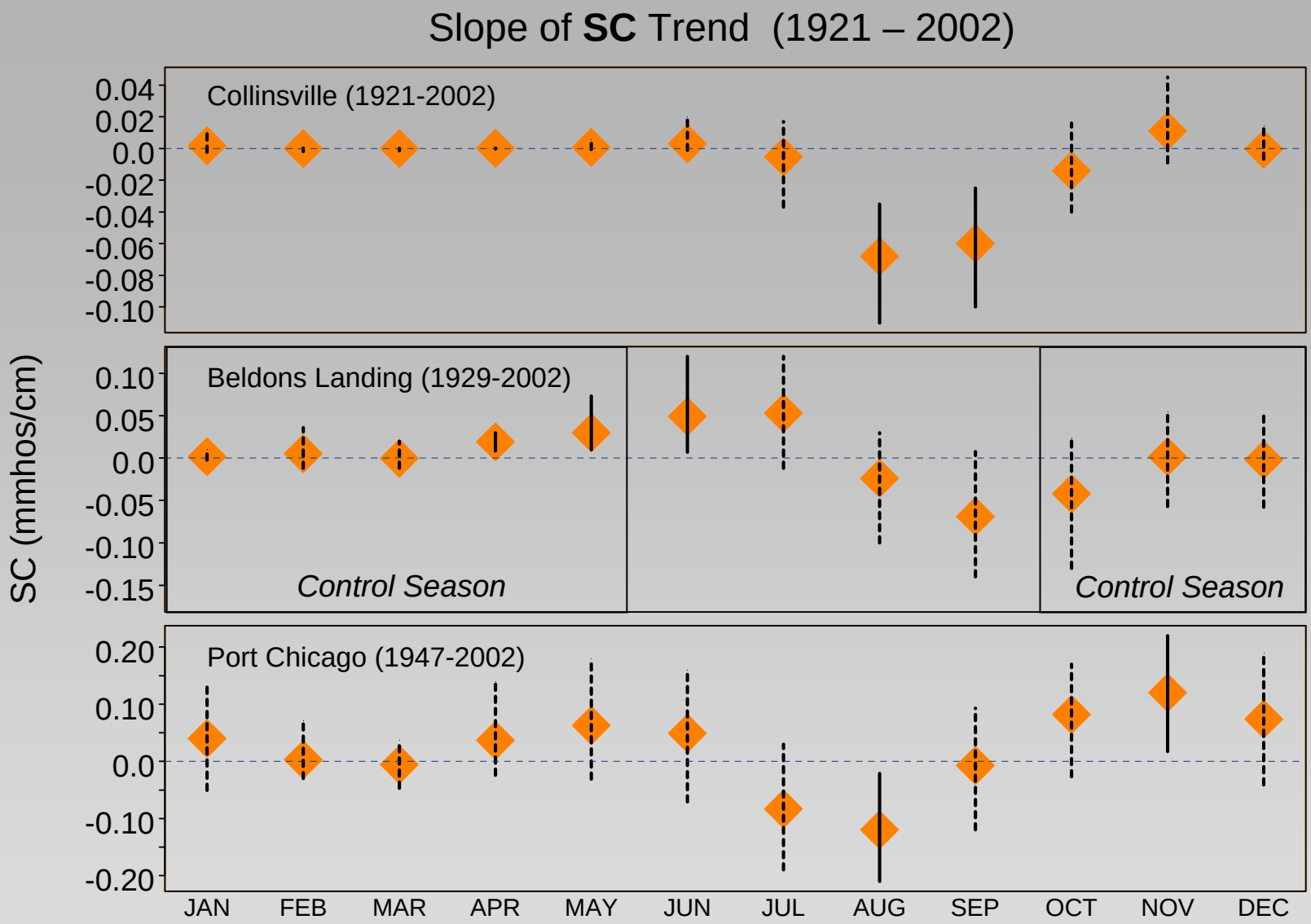
Slope of 13-Station **Precipitation** Trend (1921 – 2002)






Slope of 13-Station **Precipitation** Trend (1921 – 2002)
Precipitation (INCHES)
0.15
0.10
0.05
0.0
-0.05
-0.10
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


Slope of Delta **Outflow** Trend (1929 – 2002)
Outflow (CMS)
10
5
0
-5
-10
-15
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


Slope of **SC** Trend (1921 – 2002)
Collinsville (1921-2002)
Beldons Landing (1929-2002)
Control Season
Control Season
Port Chicago (1947-2002)
SC (mmhos/cm)
0.04
0.02
0.0
-0.02
-0.04
-0.06
-0.08
-0.10
0.10
0.05
0.0
-0.05
-0.10
-0.15
0.20
0.10
0.0
-0.10
-0.20
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

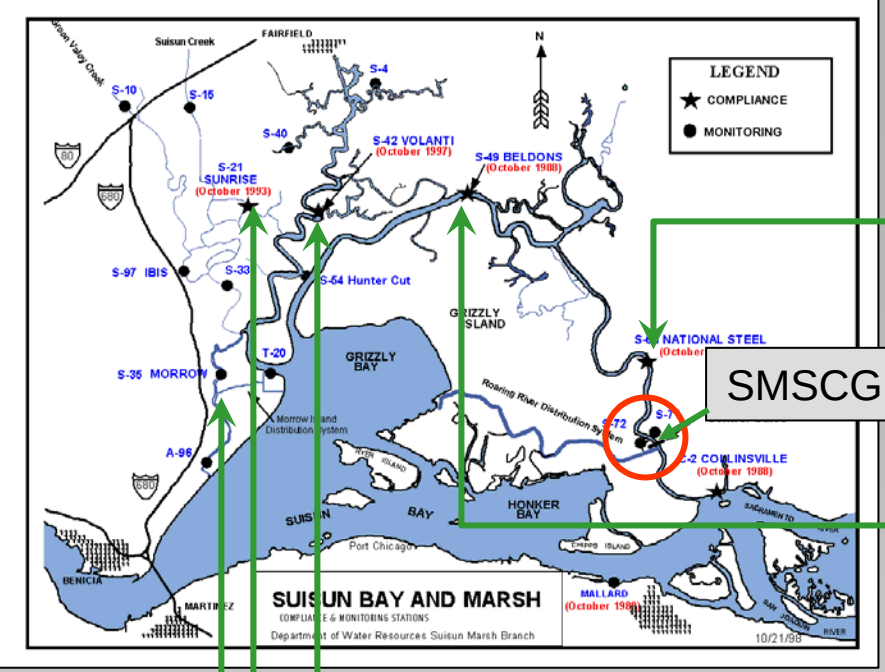
Among Month Trends:

- No significant precipitation trend any month.
- Significant decreases in Delta outflow
  - April, May, June
- Significant increases in Delta outflow
  - July August, September
- Salinity is generally coherent with outflow.
- Suggestion of decrease in October salinity trend at Beldons Landing.

5. Suisun Marsh Salinity Control Gate Effect

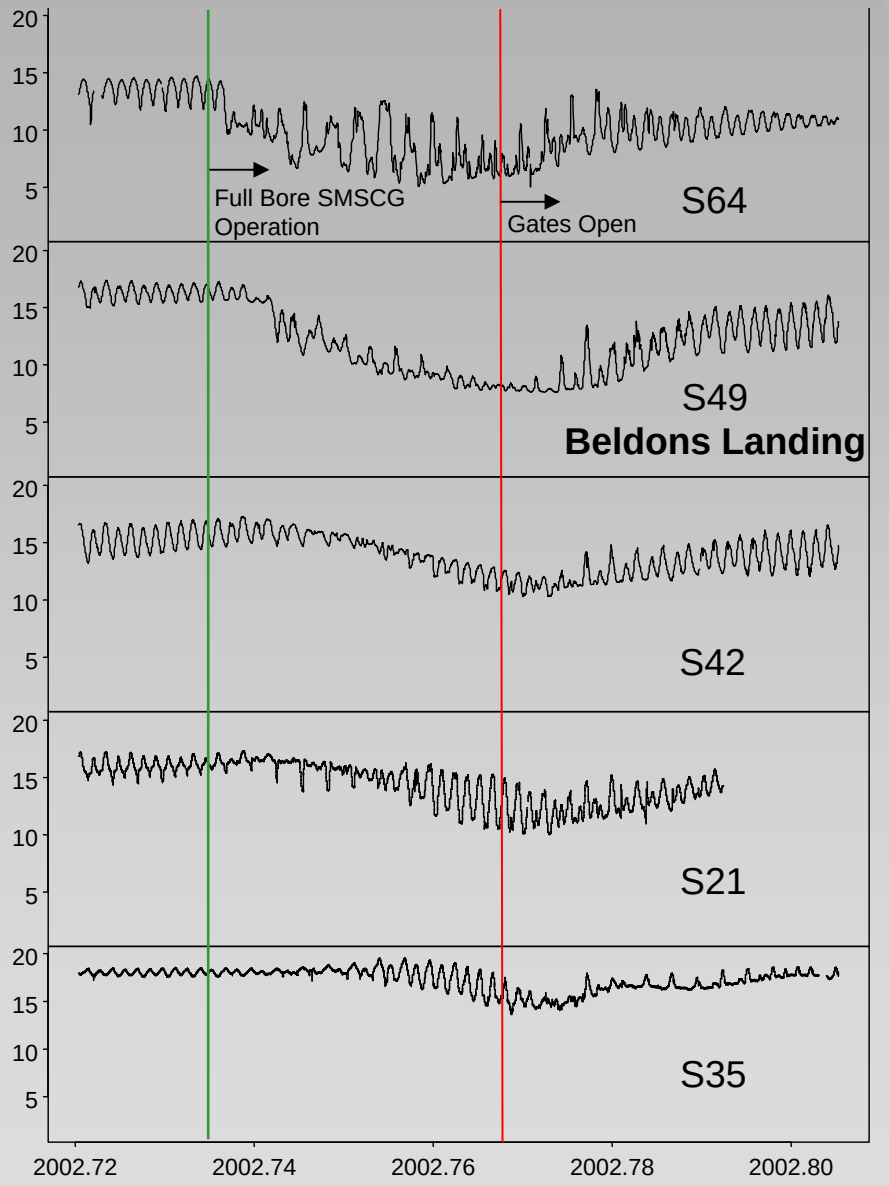
- SMSCG is operated between October and May only when needed to meet salinity standards.

Salinity Response to SMSCG Operation
Sept 20 – Oct 20, 2002



SMSCG

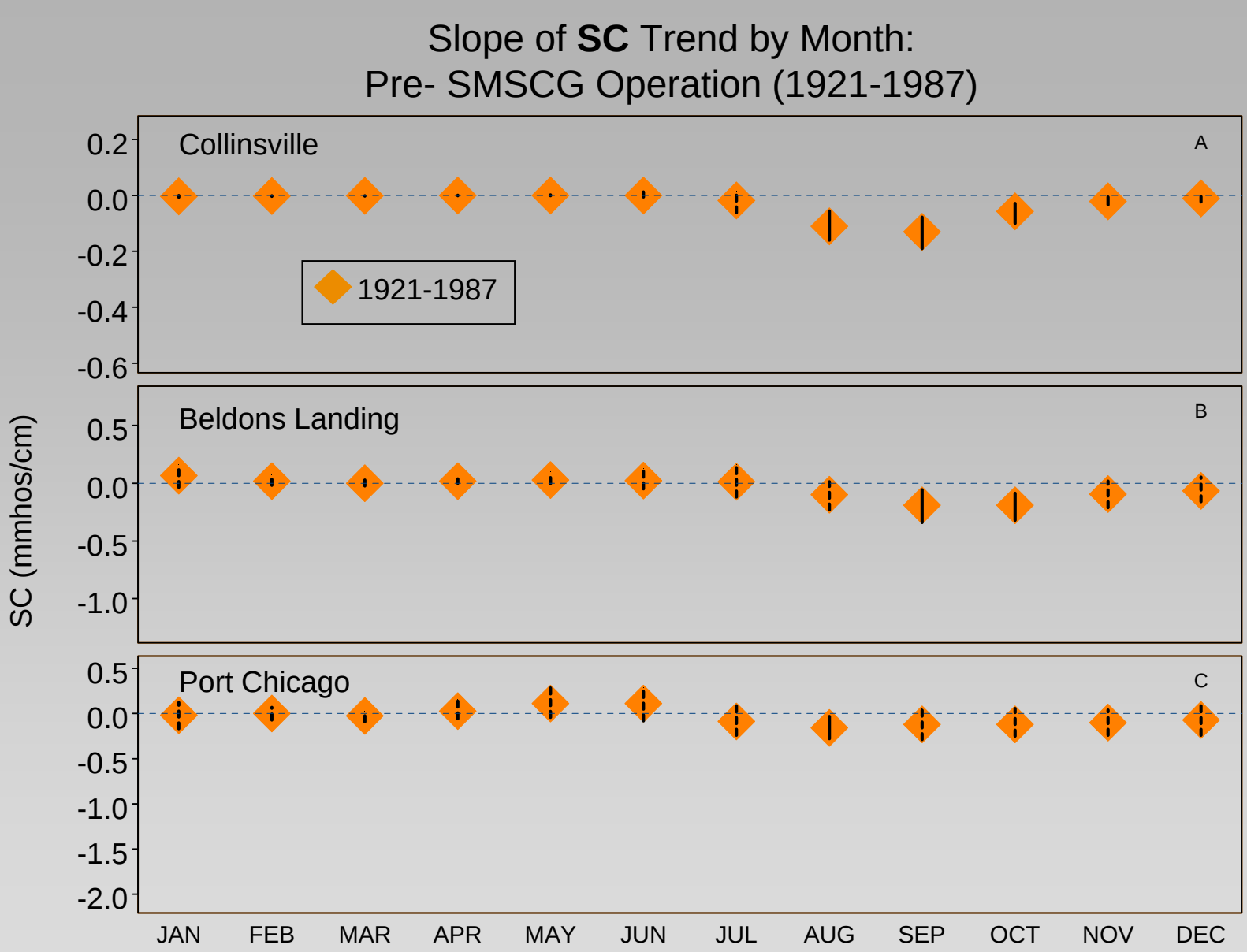
SC (mmhos/cm)

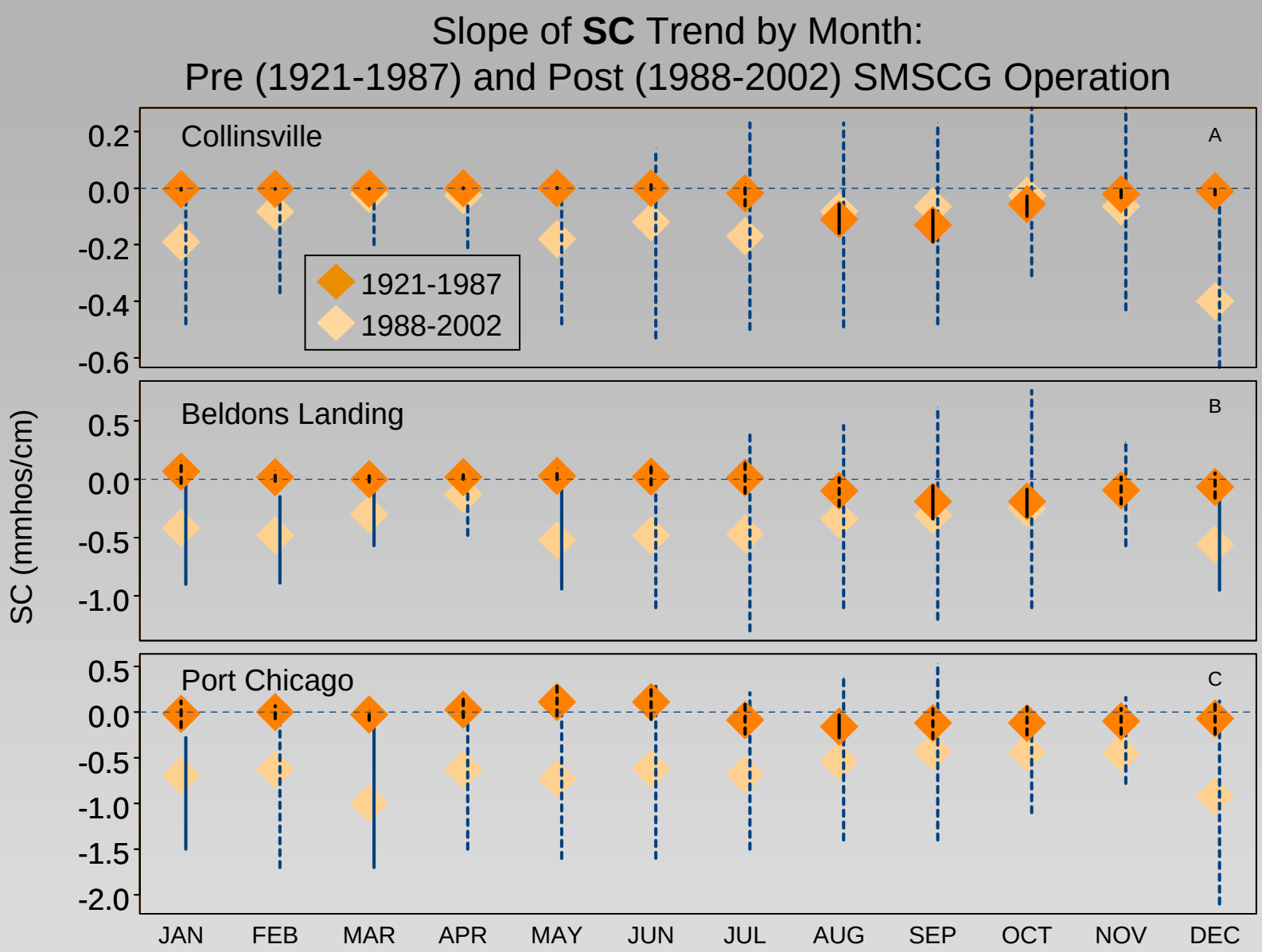


Suisun Marsh Salinity Control Gate Effect:

- Works like hell.
- Reduces Suisun Marsh salinity in the Fall (east to west):
  - S64 6-8 mmhos/cm
  - Beldons 5-7
  - S42 4-5
  - S21 3-4
  - S35 1-2

6. Salinity trends since SMSCG construction (1988)


Slope of SC Trend by Month:
Pre- SMSCG Operation (1921-1987)
Collinsville
A
Beldons Landing
B
Port Chicago
C
1921-1987
SC (mmhos/cm)
0.2
0.0
-0.2
-0.4
-0.6
0.5
0.0
-0.5
-1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


Slope of **SC** Trend by Month:
Pre (1921-1987) and Post (1988-2002) SMSCG Operation
Collinsville
A
Beldons Landing
B
Port Chicago
C
1921-1987
1988-2002
SC (mmhos/cm)
0.2
0.0
-0.2
-0.4
-0.6
0.5
0.0
-0.5
-1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Have we mitigated Suisun Marsh impacts?

SMSCG reduces Beldons Landing salinity by 5-7 mmhos/cm, however:

- Up to 1988, salinity was trending lower between August and December.
- Pre-project mean = **6.0**, s = 2.1
- Post-project mean= **7.5**, s = 3.4

7. Time-Scale Variability

- Decadal, inter-annual, seasonal, spring/neap, sub-tidal, tidal, turbulent.
- Relevant mitigation:
  - What time-scales and magnitudes of variability are important to organisms?

Annual Data CV ($s/\bar{x}$)

	Pre-Project	Post Project
Precipitation	0.57	0.75
Outflow	0.27	0.37
Collinsville	0.77	0.82
Beldons Landing	0.34	0.45
Pt. Chicago	0.25	0.35

Monthly Data CV ($s/\bar{x}$)

	Pre-Project	Post Project
Precipitation	1.18	1.42
Outflow	1.17	1.21
Collinsville	1.17	1.59
Beldons Landing	0.95	0.75
Pt. Chicago	0.65	0.71

7. Other Salinity Trend Drivers

- Sea level rise ~2mm/year
- Climate/Ocean conditions
  - (ENSO 3-5 yr, PDO 20-30 yr)
- Coastal upwelling
- Bathymetry: Suisun Bay is erosional
  - Hydraulic mining debris
  - Reservoir sediment capture
  - Ship channel dredging
  - Dredging for levee building

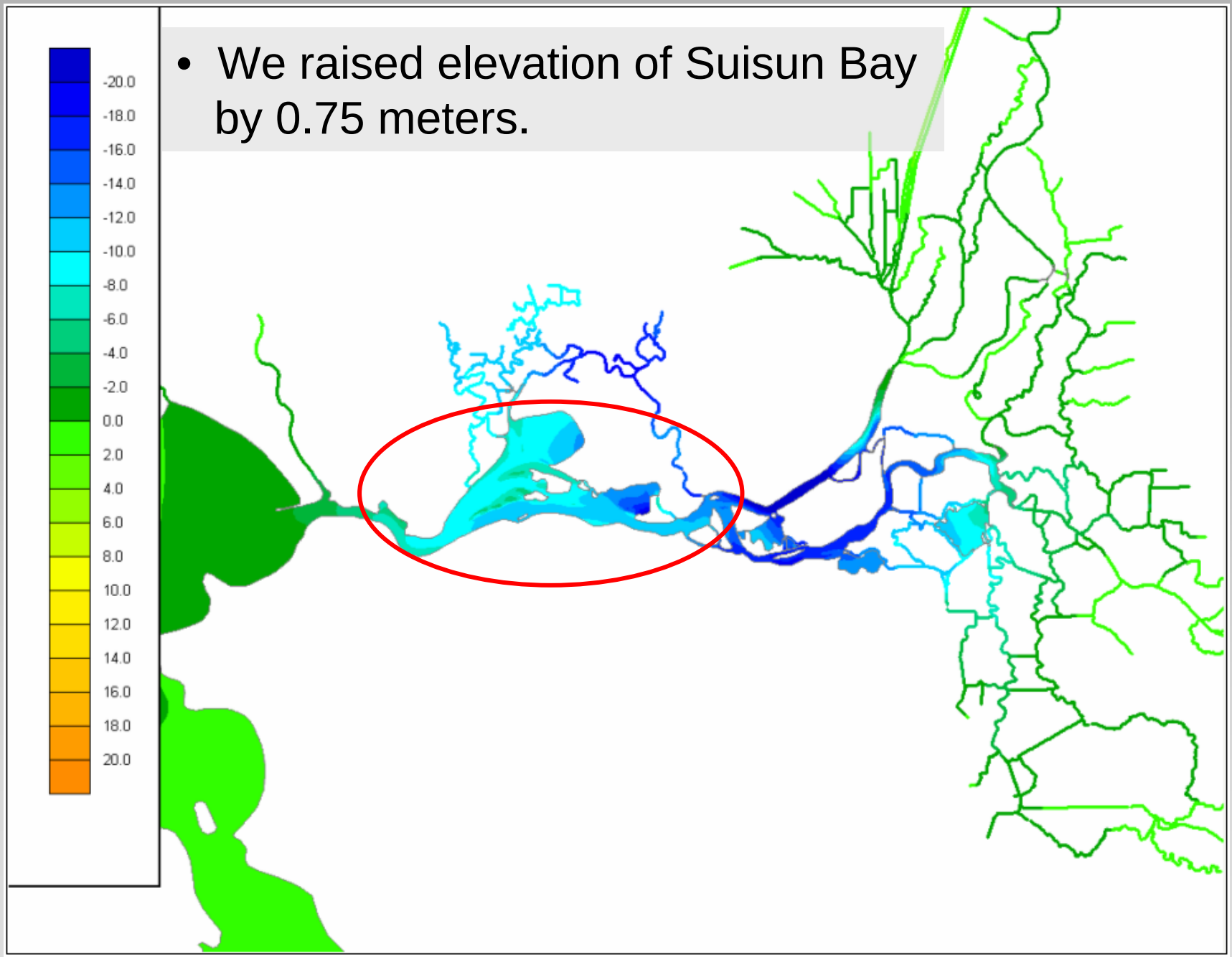
7. Other Salinity Trend Drivers

- Sea level rise ~2mm/year
- Climate/Ocean conditions
  - (ENSO 3-5 yr, PDO 20-30 yr)
- Coastal upwelling
- *Bathymetry: Suisun Bay is erosional*
  - Hydraulic mining debris
  - Reservoir sediment capture
  - Ship channel dredging
  - Dredging for levee building

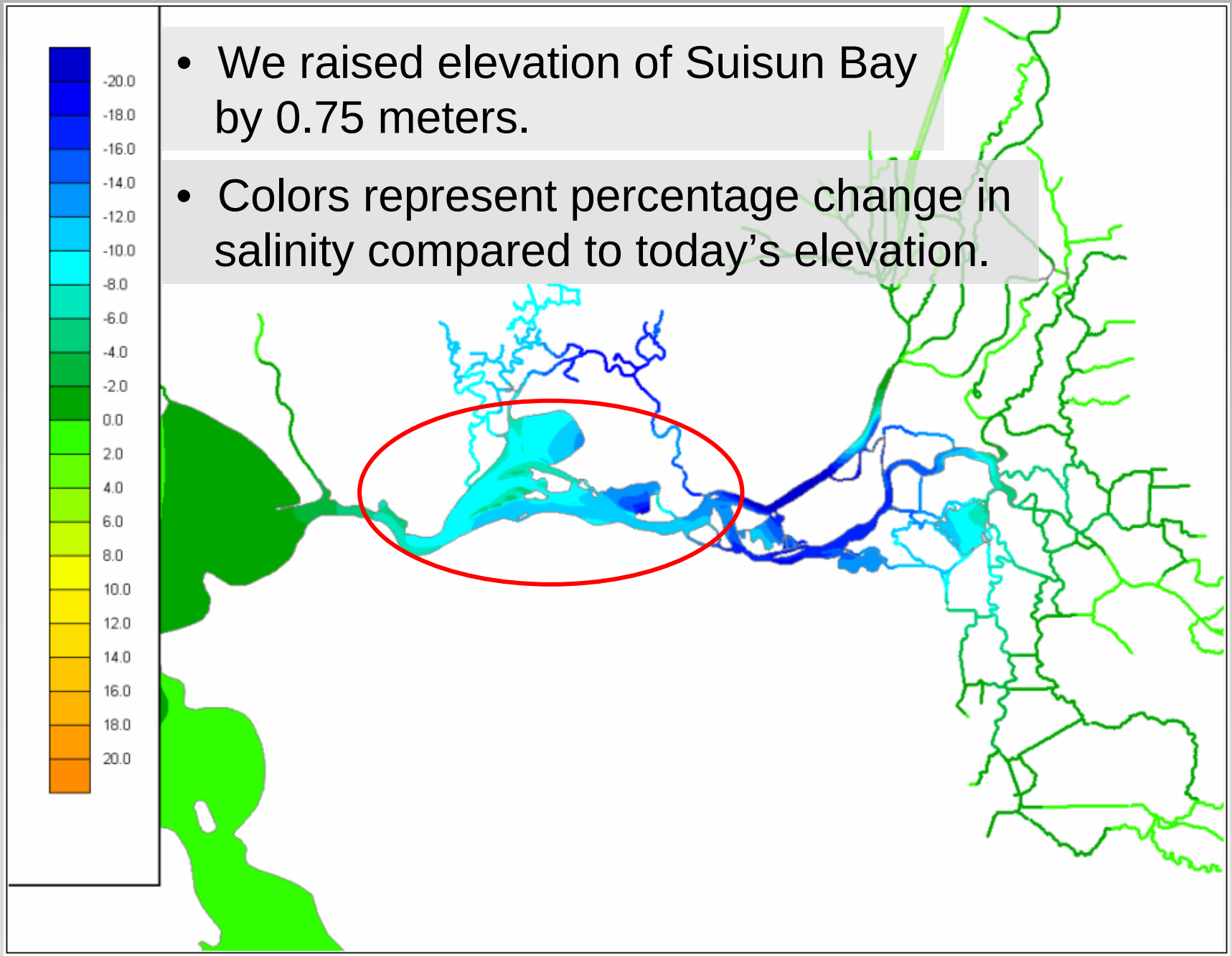
Suisun Bay Bathymetry Change

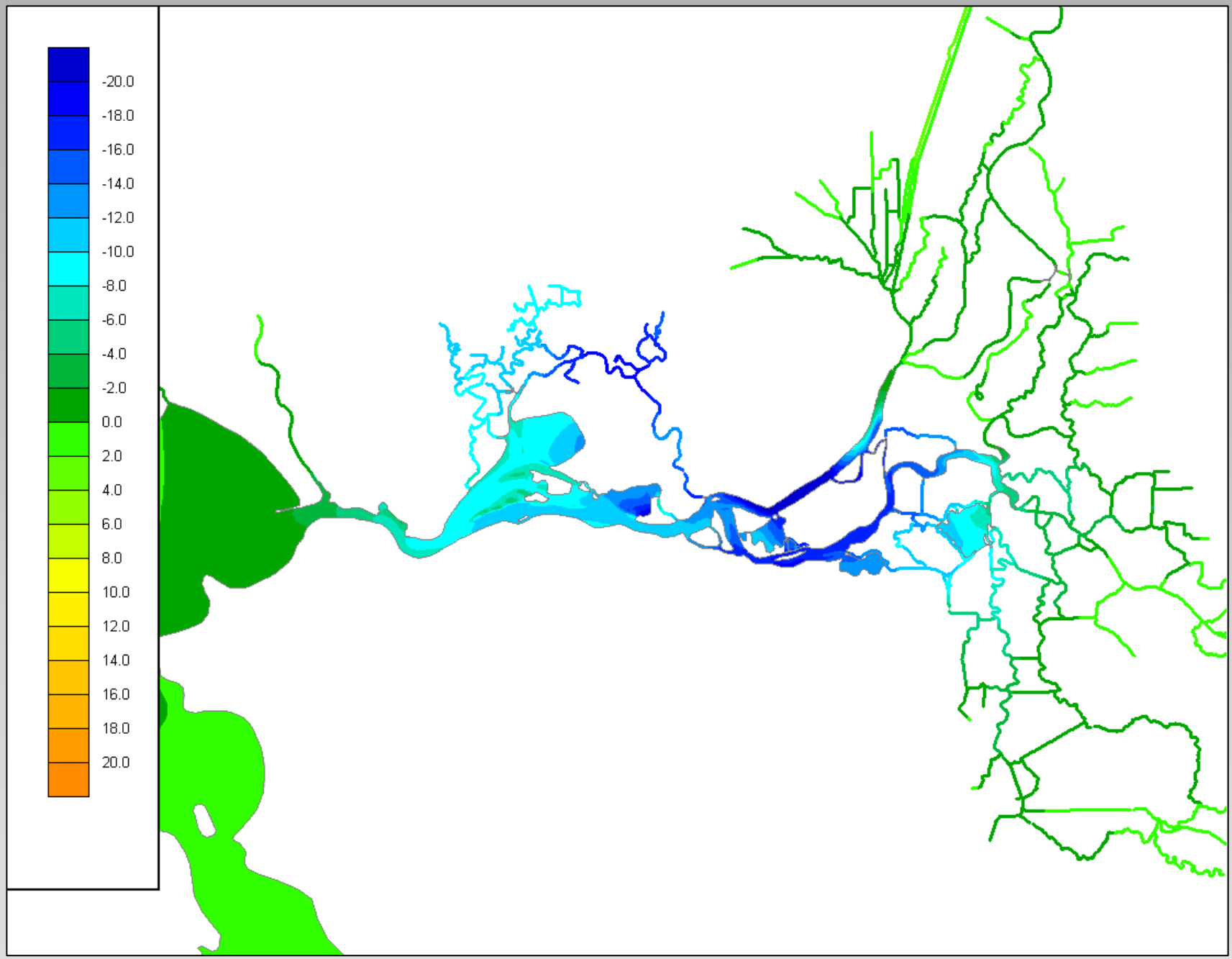
- Eroded 106 cm since 1922 (Cappiella et al.)
- > 100 million cubic meters
- How does deepening Suisun Bay affect the salinity regime? (ask Aaron Miller)

- We raised elevation of Suisun Bay by 0.75 meters.



- We raised elevation of Suisun Bay by 0.75 meters.
- Colors represent percentage change in salinity compared to today's elevation.




-20.0
-18.0
-16.0
-14.0
-12.0
-10.0
-8.0
-6.0
-4.0
-2.0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
20.0

Conclusions

Hydrology

- Long-term trend in outflow = -2.7cms/yr, ~22% reduction.
- Variability is orders of magnitude larger than all trends.
- The seasonal distribution of outflow is changed: Lower April, May, June, higher, July, August, September.

Conclusions (cont.)

Salinity

- Salinity variability is greater in post project period (coherent with precipitation)
- Climate variability overwhelms water project caused trends.
- Salinity trends are also affected by bathymetry trends.

Conclusions (cont.)

SMSCG

- Beldons annual average salinity is trending down despite increase in annual salinity at Collinsville and Pt Chicago.

- SMSCG reduces salinity more than salinity would have increased without it.

Conclusions (cont.)

Biology

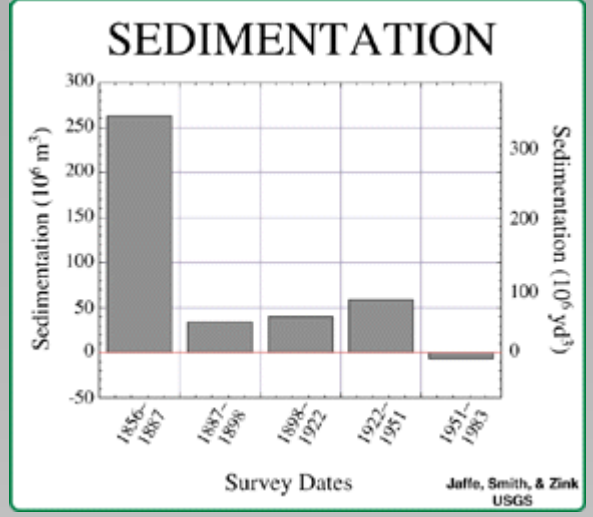
- Decrease in salinity variability from seasonal outflow redistribution is probably real, but it's overwhelmed by climate variability.
- Water projects have reduced summer/fall salinity variability some native plants/fishes have used to competitive advantage.
- Linkage between water project operations and plant/waterfowl productivity needs re-evaluation.

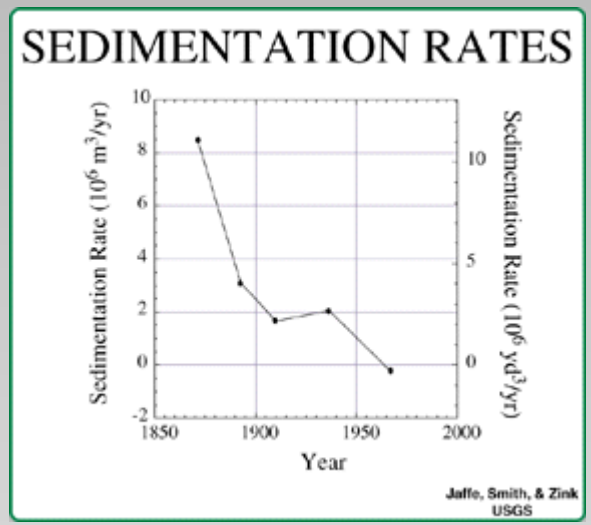
Thank You

- Callie Harrison
- Victor Pacheco
- Steve Culberson
- Marc Vayssieres
- Brad Tom
- Aaron Miller
- Kate Le
- Ted Sommer

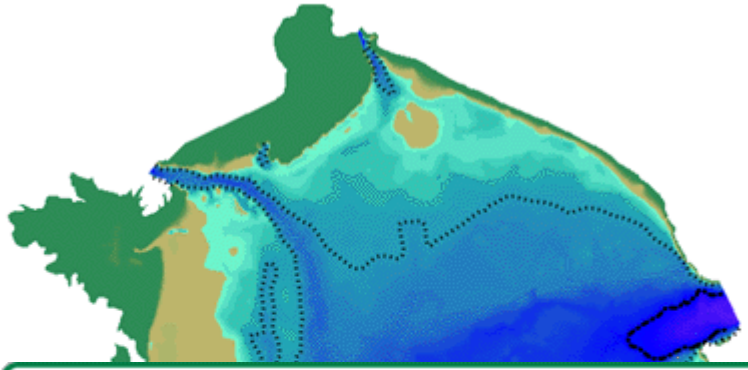
Modeling Approach

- Erosion rate = 2.4 cm/yr 1922-42 = 50.4 cm
- Erosion rate = 1.2 cm/yr 1943-90 = 56.4 cm
- Net erosion = = 106.4 cm
- Assume 1.0 cm/yr since 1990 = 11.0 cm
- Total = 117.4 cm

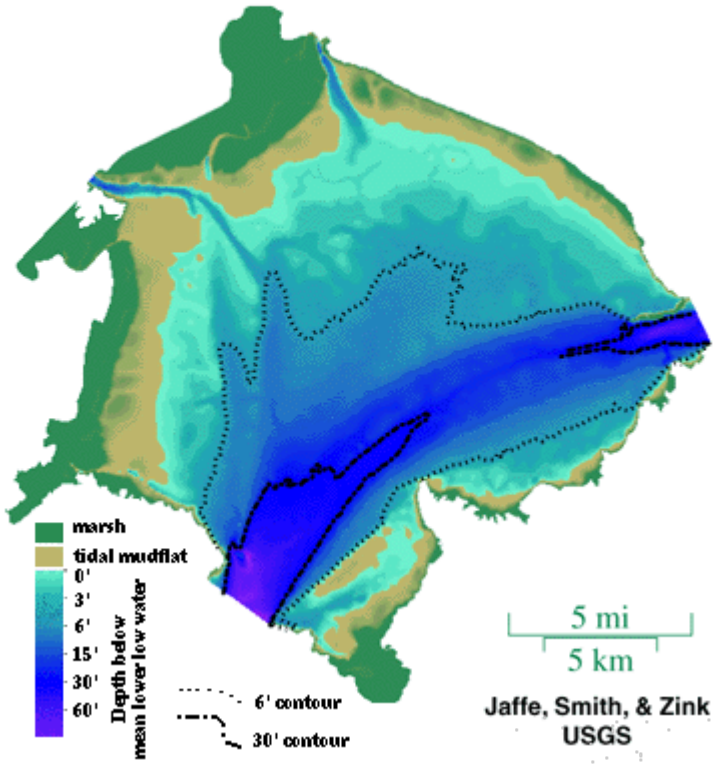

SEDIMENTATION
Sedimentation (10^6 m^3)
Sedimentation (10^6 yd^3)
300
250
200
150
100
50
0
-50
1856-1887
1887-1898
1898-1922
1922-1951
1951-1983
Survey Dates
Jaffe, Smith, & Zink
USGS


SEDIMENTATION RATES
Sedimentation Rate (10^6 m^3/yr)
Sedimentation Rate (10^6 yd^3/yr)
10
8
6
4
2
0
-2
1850
1900
1950
2000
Year
Jaffe, Smith, & Zink
USGS

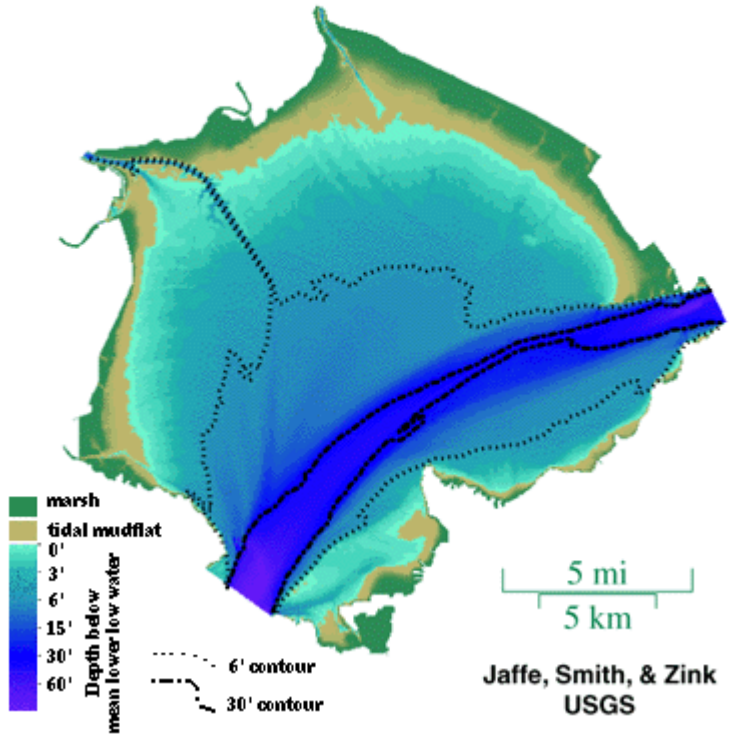
1856 SURVEY

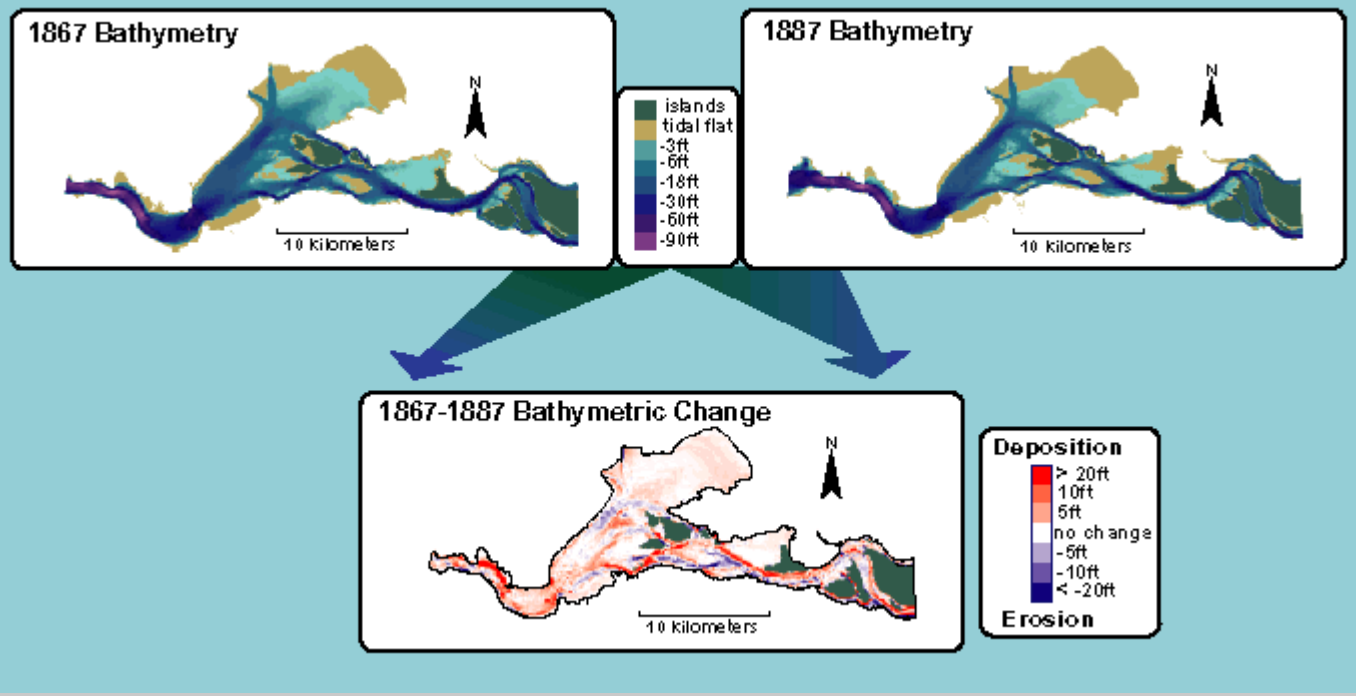


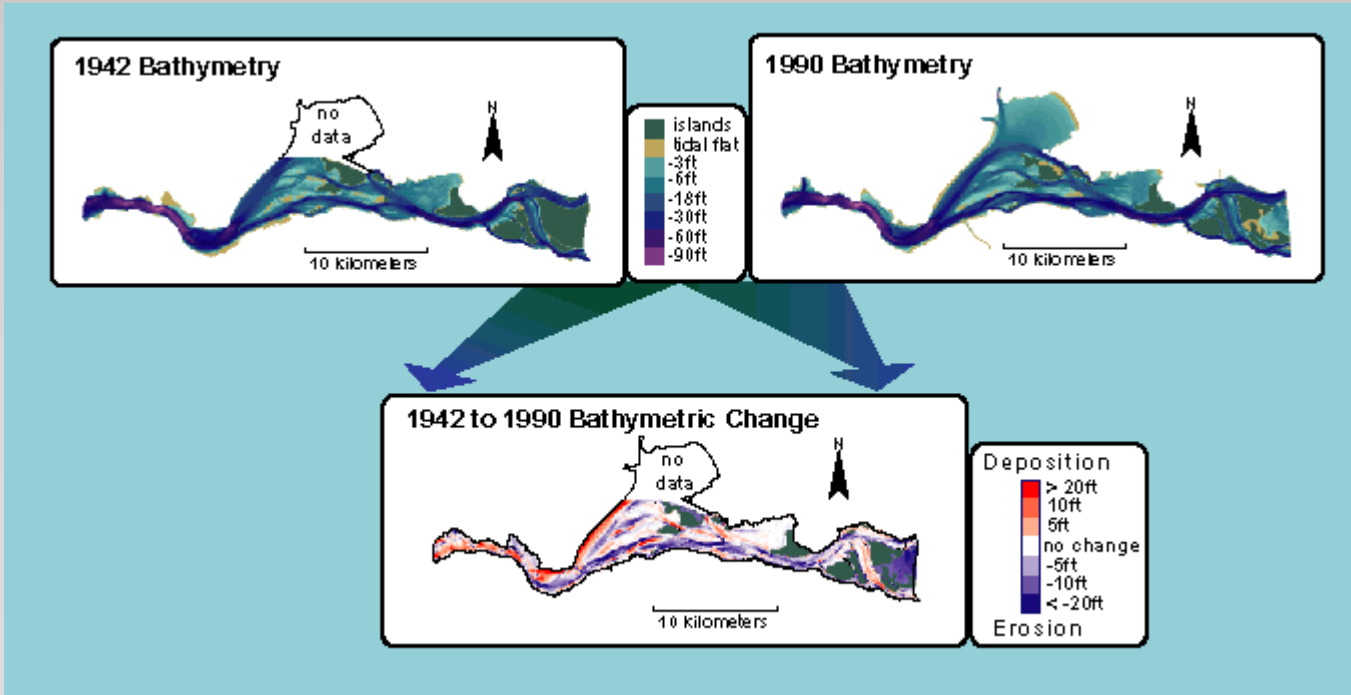
1898 SURVEY

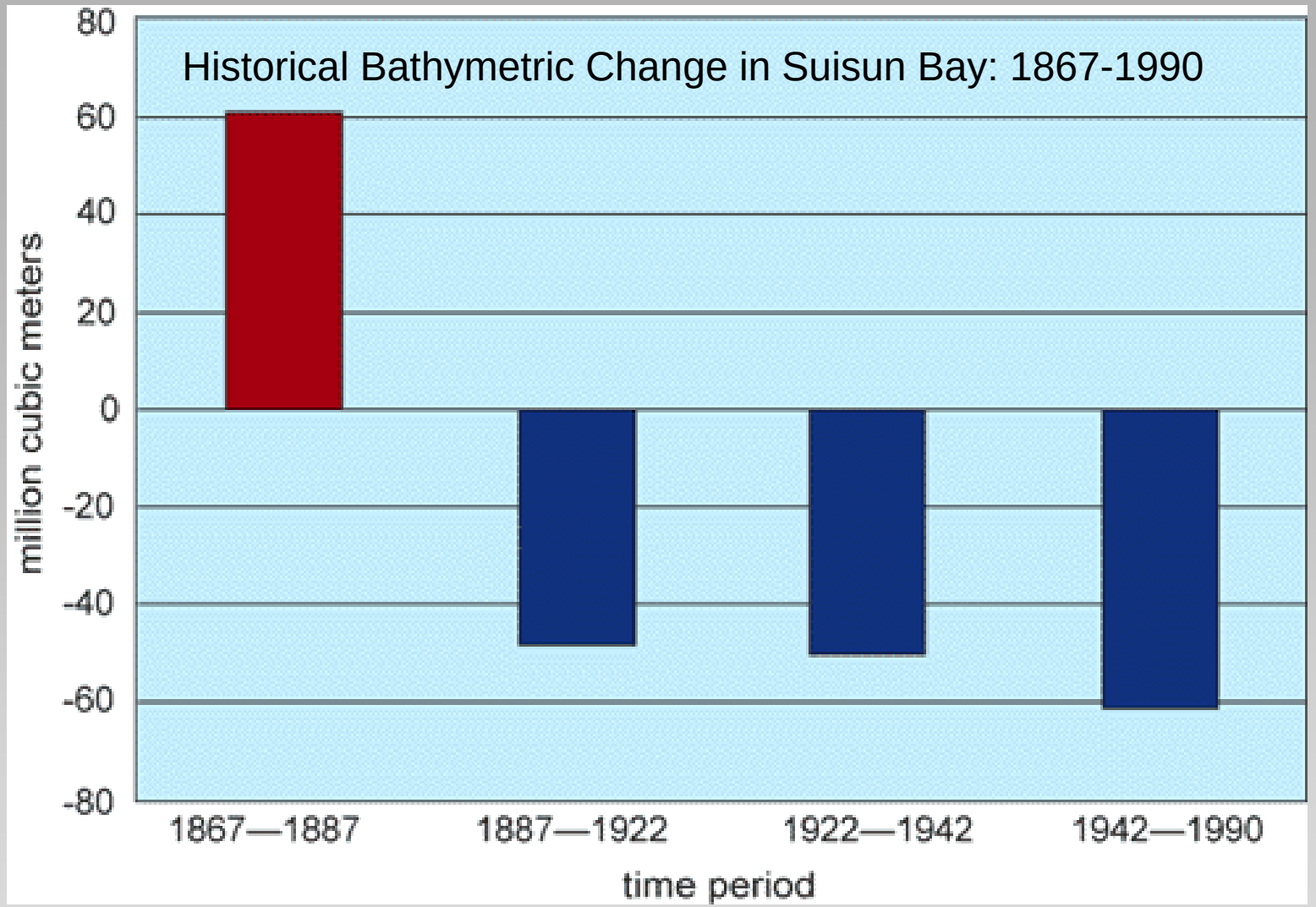


1983 SURVEY



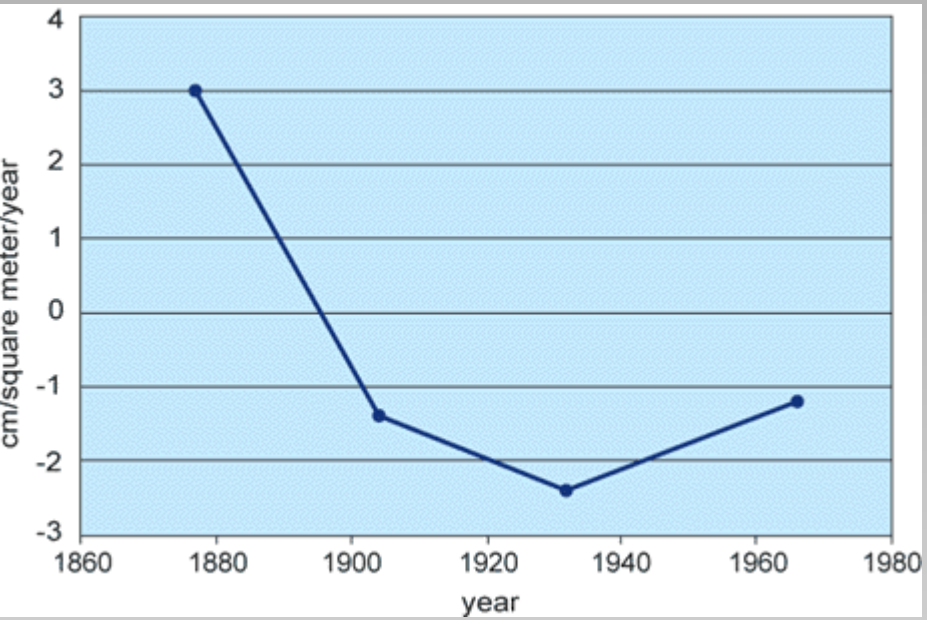

1867 Bathymetry
N
10 kilometers
islands
tidal flat
-3ft
-6ft
-18ft
-30ft
-60ft
-90ft
1887 Bathymetry
N
10 kilometers
1867-1887 Bathymetric Change
N
10 kilometers
Deposition
> 20ft
10ft
5ft
no change
-5ft
-10ft
< -20ft
Erosion


1942 Bathymetry
no data
N
10 kilometers
islands
tidal flat
-3ft
-6ft
-18ft
-30ft
-60ft
-90ft
1990 Bathymetry
N
10 kilometers
1942 to 1990 Bathymetric Change
no data
N
10 kilometers
Deposition
> 20ft
10ft
5ft
no change
-5ft
-10ft
< -20ft
Erosion

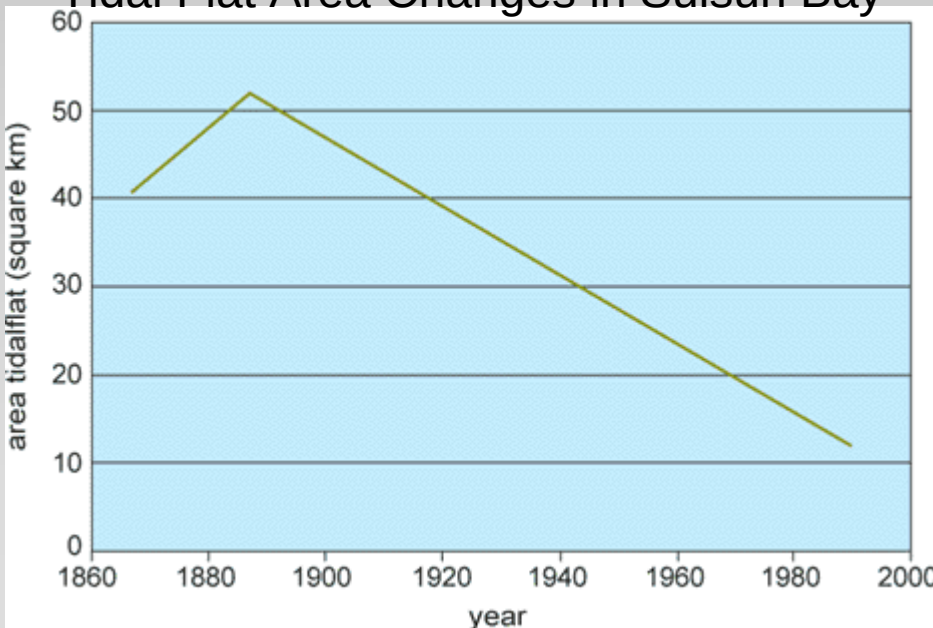


Karen Cappiella, Chris Malzone, Richard Smith, and Bruce Jaffe
USGS

Sedimentation in Suisun Bay

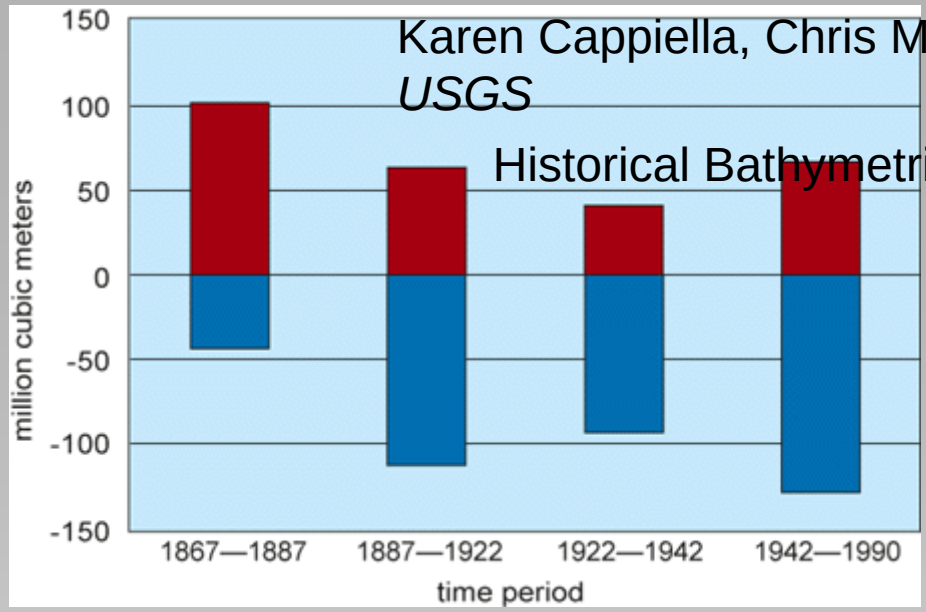


Tidal Flat Area Changes in Suisun Bay



Karen Cappiella, Chris Malzone, Richard Smith, and Bruce Jaffe
USGS

Historical Bathymetric Change in Suisun Bay: 1867-1990



Between 1867 and 1887, approximately 115 million cubic meters of sediment was deposited in the Suisun Bay area. This is equivalent to about 2.5 cm/yr accumulation over all of Suisun Bay. Almost two-thirds of Suisun Bay was depositional during this period. Most of this is debris from hydraulic gold mining in the Sierra Nevada, and is likely contaminated with mercury which was used to extract gold from tailings. Hydraulic mining ceased in 1884, while water distribution and flood control projects increased during the 20th century. These factors decreased the input of sediment to the Bay, and from 1887 to 1990 Suisun Bay was erosional.

On average, Suisun Bay deepened during the study period. From 1867 to 1990, Suisun Bay lost more than 100 million cubic meters of sediment. This is equivalent to a loss of 74 cm over the entire Suisun Bay area.
Changes in sedimentation in Suisun Bay affected its ecosystem in many ways. For example, the area of tidal flat, rich habitat, and sources of sediment to the wetlands increased by approximately 10 square km from 1867 to 1887 due to the input of hydraulic mining debris. From 1887 to 1990, however, tidal flat area decreased from 52 square km to 12 square km.